make ammeter readings meaningful. The temperature should be checked sufficiently upstream and downstream of the heater to ensure an adequate rise in air temperature. The readings obtained also should be evaluated by a cognizant individual to ensure the desired RH can be achieved with the potential minimum and maximum environmental temperatures in the inlet stream.

## 8.6 SURVEILLANCE TESTING

There are three types of surveillance tests: (1) in-place leak tests of HEPA filter stages using an accepted test aerosol, (2) in-place leak tests of adsorber stages using a slightly adsorbable gas such as the fluorocarbon Refrigerant-11, and (3) laboratory tests of samples of adsorbent withdrawn from the system to establish its remaining adsorption capacity. These tests are also employed as part of the acceptance procedure for new installations, with the exception that laboratory tests are made on samples of adsorbent taken from batch material as furnished.

Surveillance tests of HEPA filter and adsorber systems should be made at regular intervals after installation to detect deterioration and leaks that may develop under service conditions. Regular in-place testing of standby systems is necessary because deterioration can take place even when the systems are not being operated. Aside from component damage, frequently discovered causes of failure to meet in-place test requirements include loose clamping bolts; inadequate clamping devices; foreign material trapped between gaskets and mounting frames, rough or warped mounting frame surfaces; cracked welds; unwelded joints in mounting frames; ground settlement; incorrectly installed components (e.g., HEPA filters installed with horizontal pleats); inadequate seals between mounting frames and housings; poorly designed mounting frames; and bypasses through or around conduits, ducts, or pipes that penetrate or bypass the mounting frames.

### 8.6.1 IN-PLACE LEAK TEST, HEPA FILTER BANKS

Section 8 and 9 of ASME N510[10] are prerequisites for the HEPA filter in-place leak test. In cases where there are multiple series or parallel HEPA banks and associated bypass leakage paths, the guidance outlined in Section 13 of ASME N510, "System Bypass Test," should be followed. The proper procedure to be used with dual HEPA filter banks is to introduce a test aerosol at the predetermined, qualified location (the test port) upstream of the first bank, and then determine a downstream reading of the first bank between the two filters (the second bank will block any leakage). If this determination is satisfactory, then while injecting at a point (or through a manifold) upstream of the second HEPA filter bank (between the banks), readings should be taken downstream of the second HEPA filter bank, preferably downstream of the fan. This test should be performed every time on every unit where two HEPA banks in series are installed.

There are three major types of in-place testing methods. The first test method uses a light-scattering photometer with a polydispersed aerosol. The second method uses a shroud and/or scanning test technique, and the third uses a laser spectrometer in lieu of the forward light-scattering photometer. Due to differences in the designs of HEPA filter plenums throughout the DOE complex, as well as corresponding differences in testing techniques, the Defense Nuclear Facilities Safety Board recognized a need to standardize methods for in-place testing at DOE sites. To address this need, a conference was held at the DOE Savannah River Site (SRS) to exchange information about the sharing of in-place testing technology among DOE contractors.[18] The conference concluded that all DOE sites basically used the same type of penetrometer, with the exception of LANL, which uses the laser spectrometer. In-place tests of HEPA filter installations are made with a polydispersed test aerosol consisting of droplets with a light-scattering number mean diameter (NMD) of 0.7 μm and a size range of approximately 0.1 to 3.0 μm.[10] The test aerosol used for efficiency testing by manufacturers and DOE's Filter Test Facility (ORFTF) is a monodispersed aerosol with a light-scattering NMD of $0.3 \pm 0.03$ μm. The in-place test is made by challenging the upstream side of the filter or filter bank with test aerosol smoke, then measuring and comparing (using a light-scattering photometer) the test aerosol concentration in samples of downstream (filtered) and upstream (unfiltered) air (**FIGURE 8.5**). If the system


Figure 8.5 – Commercially available packaged forward-light scattering photometer for HEPA filter in-place testing

exceeds the specified maximum permissible penetration value, the downstream faces of the filters and mounting frame can be scanned with the photometer probe to locate localized high concentrations of test aerosol, indicating leaks.

**FIGURE 8.6** illustrates the basic equipment and a schematic of a standard test arrangement. The instrument shown is a forward-light-scattering photometer with a threshold sensitivity of at least $10^{-3}$ μg/L for 0.2- to 1.0-μm particles, and a sampling rate of at least 1.0 cfm is recommended.[10] The instrument should be capable of measuring concentrations $10^5$ times the lower detection limit. Compact self-contained instrument packages are commercially available (FIGURE 8.5). Polydispersed aerosol may be generated thermally or by compressed air. Compressed-air generators are widely used for testing small systems. They are commercially available or can be homemade in sizes from 1 to 24 nozzles, as shown in **FIGURE 8.7**. A rule of thumb for determining generator capacity is to allow one Laskin nozzle per 500 cfm of installed filter capacity. Compressed-air generators are suitable for systems up to about 3,000 cfm; above this size they become cumbersome.[8] Although gas-thermal generators are generally used for testing systems of 20,000 cfm installed capacity and larger, they have too much output for small systems (FIGURE 8.7). The engineer must not confuse this type of generator with the equipment used by manufacturers or the DOE ORFTF for predelivery efficiency testing of HEPA filters (**FIGURE 8.8**). The gas-thermal generator produces a polydispersed aerosol of about the same NMD and size range as the compressed-air generator. It is also small and can generally produce enough aerosol at a concentration of 40 to 50 μg of test aerosol/L to test banks up to 30,000 cfm installed capacity. Nitrogen must be used with thermal systems to avoid causing fires.

A detailed description of the procedure for conducting an in-place test of HEPA filters is given in Section 10 of ANSI N510[10] and in ASME AG-1, Appendix TA-V.[3] A prerequisite of the test is a demonstrated ability to achieve good mixing of the test aerosol and air at the upstream and downstream sample points (Section 9, ANSI N510[10]). For systems in which good mixing cannot be achieved, multipoint sampling and averaging may be used, in accordance with Section 11 of ANSI N510.[10]

For installations that are designed in accordance with this handbook and employ HEPA filters that have been tested by the DOE ORFTF, an acceptance criterion of 0.05 percent maximum penetration is recommended for the test aerosol test.

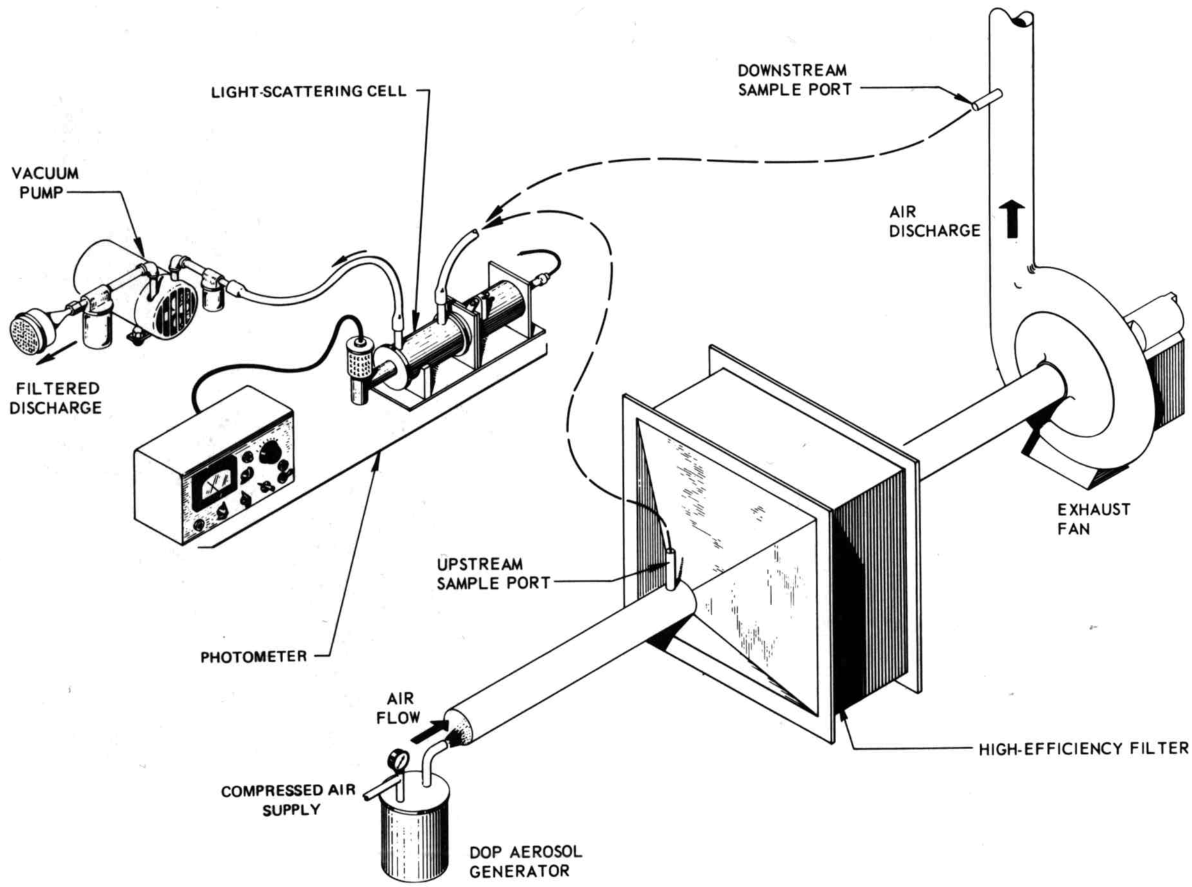



Figure 8.6 – Equipment arrangement, in-place testing of HEPA filters

For the shroud/scan in-place test method (**FIGURE 8.9**), ASME N510 (1989),[43] the photometer, generator, and test aerosol are the same as those used in the standard test method described above.

A manifold is installed in the upstream and downstream shroud. The upstream shroud must be placed over a filter, and the generator turned on. It is important to verify that the aerosol mist is filling the shroud using an upstream sample/challenge manifold located in the shroud. When the 100 percent upstream concentration is obtained, the meter stray-light is set to zero and the downstream reading is taken. If the downstream shroud method is used, the sample tube must be connected to the downstream shroud manifold, and the downstream shroud must be placed against the frame of the filter to be tested for a minimum of 15 ± 5 sec, as determined by the photometer operator. If the downstream scan method of testing is used, each filter and gasket must be probed. The photometer is then read, and the highest leak rate reading is recorded "As Found". The final leak rate readings are recorded in the lower right corner of the applicable data box.

To calculate leak rates, the leak rate readings from the data boxes for "As Found" and "Final" are added together and the sum is recorded. This total is then divided by the number of filters in the filter stage, and the result is recorded, as expressed below.

$$\frac{\text{Sum (As Found or Final)}}{\text{Total Number of Filters}} = \text{Overall (As Found or Final) Leak Rate}$$

Overall efficiency is determined by subtracting the overall leak rates ("As Found" and "Final") are subtracted from 100 percent and recording the result, as expressed below.

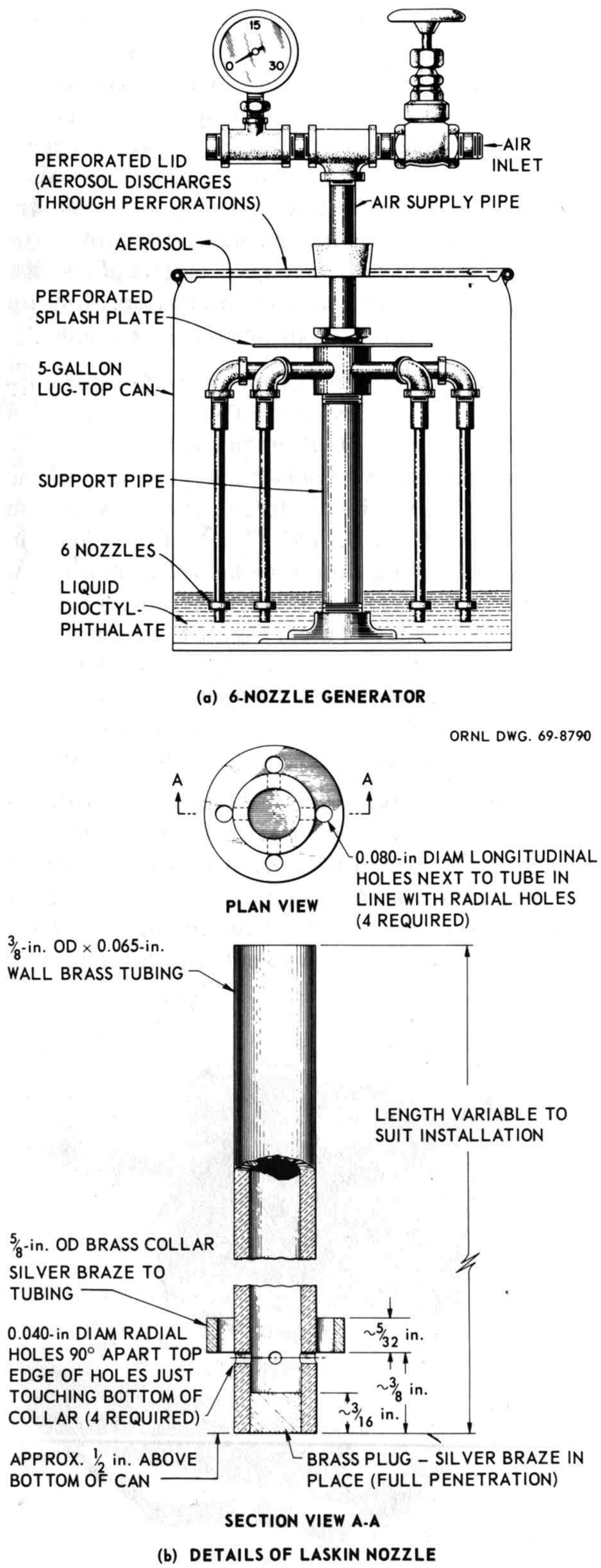



Figure 8.7 – Compressed air-operated aerosol generator

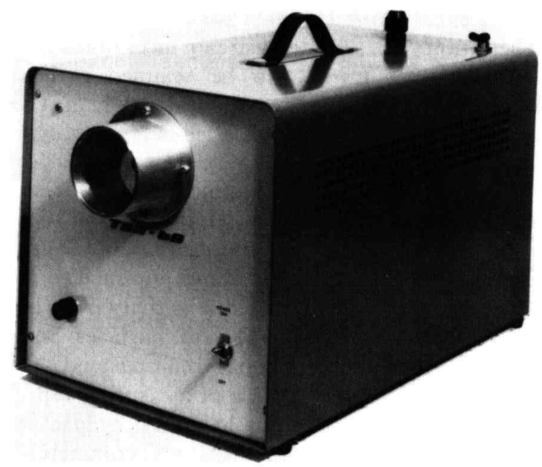


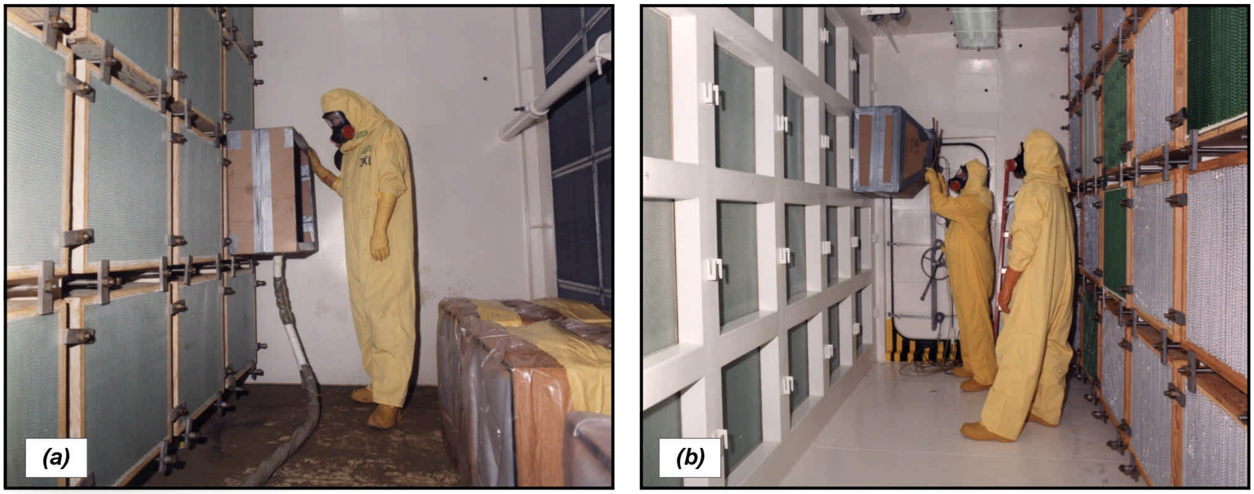
Figure 8.8 – Gas-thermal aerosol generator

100 percent – Overall ("As Found" or "Final") Leak Rates = Overall (As Found or Final) Efficiency

A third test method, the single-particle particle-size spectrometer (SPPSS), was implemented at LANL using the guidelines of NEF3-41T.[19] This modified procedure uses a laser particle size spectrometer with the capability of counting single particles downstream of two filter stages where DF of the first stage and overall system effectiveness are established. DF measurements as high as 10 were obtained,[9] indicating a high level of sensitivity that can be used on single-stage filters. The advantage of the SPPSS method is that it provides information on system performance without interruption of process ventilation, resulting in corresponding savings in operational costs that are highly beneficial. The downside is that the instrument is prone to malfunction, being a laboratory-type instrument, and is heavy, cumbersome, and expensive.

### 8.6.2 IN-PLACE TESTING FOR ADSORBERS

The in-place leak test of the adsorber bank (stage) measures bypass (mechanical) leakage around or through the installed adsorber bank. This test may be performed (1) as an acceptance test to verify system design function following initial field installation; (2) after an abnormal incident, replacement, repair, or modification that may affect design function; or (3) as a periodical in-




Upstream Aerosol Generation

Downstream Sampling

Figure 8.9 – Shroud test

service (surveillance) test to monitor system condition and operational readiness.

Bypass leakage around the adsorber bank (stage) may result from mounting frame weld degradation, damaged or poorly compressed gaskets, common drains between housing compartments, common electrical conduits between housing compartments, and inadequately dampered bypass ducts. Bypass leakage through the adsorbent media may be due to poor adsorbent filling technique and subsequent settling from system vibration and air or gas pulsation.

Since the in-place leak test only provides a measure of bypass leakage, this test is often performed in conjunction with the laboratory test of the adsorbent media. Assuring that the adsorber bank meets bypass leakage acceptance criteria and the adsorbent media itself performs adequately provides the necessary information required to determine whether the adsorber bank is performing as designed.

There are two methods commonly used for in-place leak testing of the adsorber bank stage. One uses a fluorocarbon refrigerant gas or an alternative tracer gas. The other uses a radioactive tracer gas (iodine or methyl iodide). The first method, developed by Savannah River Laboratory,[27] is the most frequently used, particularly in commercial applications. The second method involves the use of radioactive isotopes and personnel licensed to handle them. This test should not be confused with a laboratory test of adsorbent media. Radioiodine tracer methods were developed primarily for DOE installations.[22, 23] Both in-place tests are leak tests designed to measure bypass leakage, and they must be supplemented with laboratory tests of samples taken from the adsorbers at the time of the in-place test to determine system leak tightness and the radioiodine removal efficiency of the adsorbent media. For commercial nuclear power plants, typical bypass leakage acceptance criteria for the adsorber bank (stage) range from 1.0 percent to 0.05 percent of rated flow, depending on specific plant license bases. The current USNRC Regulatory Guide[13] requires that in-place leak testing for adsorbers be performed (1) initially; (2) at least once each 24 months; (3) following the removal of an adsorber sample for laboratory testing if the integrity of the adsorber section is affected; (4) after each partial or complete replacement of a carbon adsorber in an adsorber section; (5) following detection or evidence of penetration or intrusion of water or other material into any portion of an ESF atmosphere cleanup system that may have an adverse effect on the functional capability of the adsorber; and (6) following painting, fire, or chemical release in any ventilation zone communicating with the system that may have an adverse effect on the functional capability of the system. The Regulatory Guide further specifies that the in-place leak test should be performed in accordance with Section 11 of ASME N510-

1989[10] and the in-place leak test should confirm a combined penetration and bypass leakage quantity around or through the adsorber of 0.05 percent or less test aerosol at system rated flow of ± 10 percent.

#### 8.6.2.1 NONRADIOACTIVE TRACER GAS TEST

The first test, commonly referred to as the Freon[24] test, is made by challenging the upstream side of the adsorber with a slightly adsorbable and readily desorbed fluorocarbon gas [usually Refrigerant-11, trichloro (mono) fluoromethane], then determining the concentrations immediately upstream of the adsorber bank and at a point downstream of the adsorber bank where satisfactory mixing with air occurs. Bypass leakage is calculated from the ratio of downstream-to-upstream reading, as follows.

$$\text{Percentage Bypass Leakage} = \text{Reading Downstream} / \text{Reading Upstream}$$

Since it is the *ratio* of concentrations that matter, the units may be expressed in terms of peak height or some other measure directly related to tracer concentration, although the measure may not necessarily reflect the actual volumetric or mass tracer concentration.

Refrigerant-112 was originally used, but is no longer produced. Refrigerant-112 was more strongly adsorbed by the adsorbent bed than Refrigerant-11 and allowed testing of banks under conditions of high RH or elevated adsorbent moisture content. With the introduction of ASME AG-1,[3] alternative, substitute tracer gases are allowed (permitting tracer gases with stronger adsorption potentials than Refrigerant-11), providing the selection is made in accordance with the AG-1, Appendix TA-C, selection criteria.[3] Noncommercial installations have successfully used alternative tracer gases (e.g., PDCB[25]). When the carbon beds nondestructive test was developed, testing equipment consisted of a pump to draw upstream and downstream air samples from the adsorber system, two identical gas chromatographs with electron-capture detectors for measuring refrigerant gas concentrations, a timer, and several rotameters for determining sample dilution factors. The chromatographs had a linear range of about 1 to 100 ppb (by volume) for detection of the refrigerant gas. Since the upstream concentration exceeded the linear range of the instrument, the sample was diluted with a known volume of air to bring it within the detection range of the chromatograph. Calibrated rotameters were used to determine the dilution factors. Currently, two types of equipment are used to perform this test. Traditional, noncontinuous chromatographs have been developed specifically for in-place leak testing, eliminating the need for rotameter dilution and providing microprocessor-based leak rate calculation. Modern chromatograph-based equipment used for the adsorbent in-place leak tests is shown in **FIGURE 8.10**. Continuously monitoring detectors, considered an untraditional approach, also are used, as shown in **FIGURE 8.11**. **FIGURE 8.12** shows a schematic of the test setup. Prefilters and HEPA filters in housings have no effect on the nonradioactive tracer gas test. The test should be performed by experienced, trained personnel, and should be conducted in accordance with prescribed procedures (Section 11, ANSI N510).[10] Use of the mixer shown in FIGURE 8.12 is not necessary if samples can be taken from an area that assures good mixing, e.g., downstream of the fan or downstream of duct bends or transitions that

Figure 8.10 – Modern chromotograph based equipment

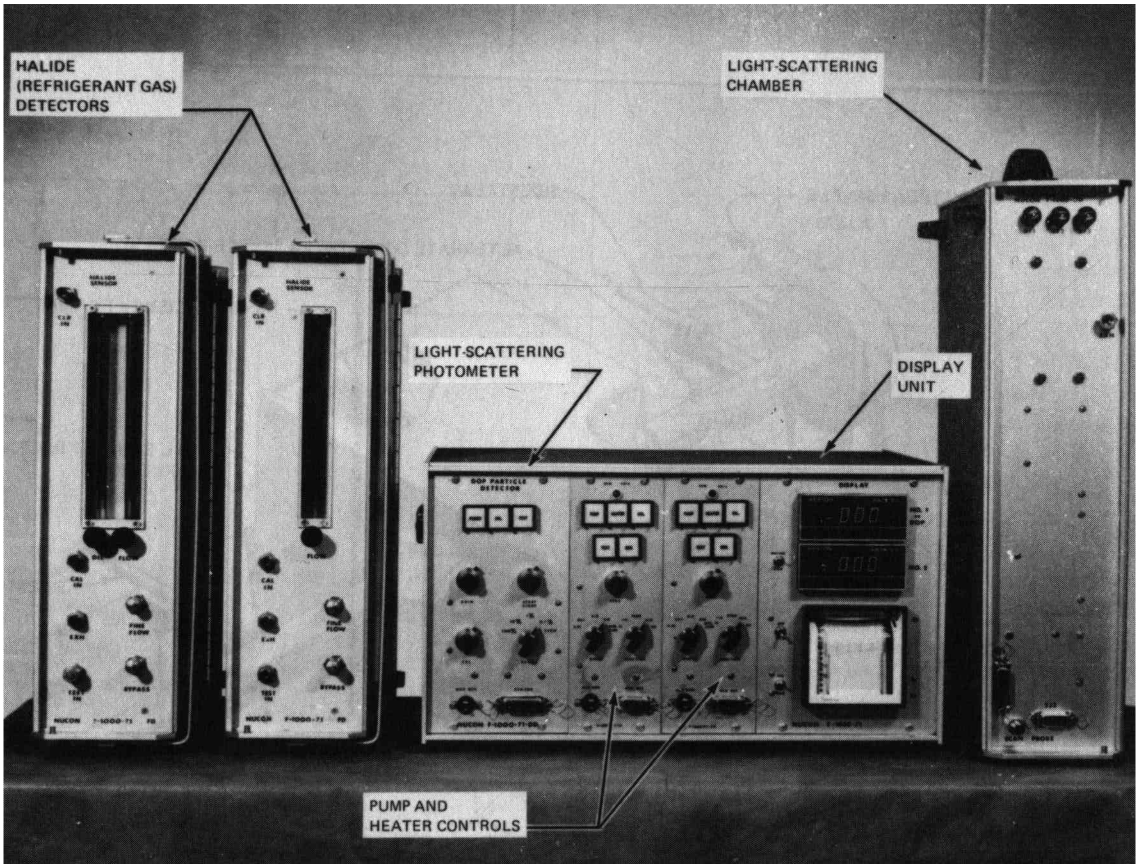



Figure 8.11 – Continuous monitoring charcoal testing equipment

introduce turbulence into the air stream. Where good mixing cannot be achieved, temporary or permanently installed sampling manifolds constructed in accordance with ANSI N509, Appendix D,[32] are sometimes used.

### 8.6.2.2 Radioactive Iodine Tests

These tests are currently used for routine adsorber-bank testing at Oak Ridge National Laboratory (ORNL) and the Hanford (Richland, Washington) facilities of DOE. Two tests are used, one with radioactively traced elemental iodine, and the second with radioactively traced methyl iodide. Equipment requirements for the elemental iodine test include an iodine injection tube (**FIGURE 8.13**), two sampling units (**FIGURE 8.14**), a sample extraction pump, and three calibrated rotameters for controlling the injection and sampling flows. The sampling units are filled with charcoal of known efficiency for elemental iodine. The test aerosol is iodide-127 containing the iodide-131 tracer. A combination of injected radioactivity (in microcuries), sampling rate, and counting technique (usually dictated by the kind of counting equipment available) must be

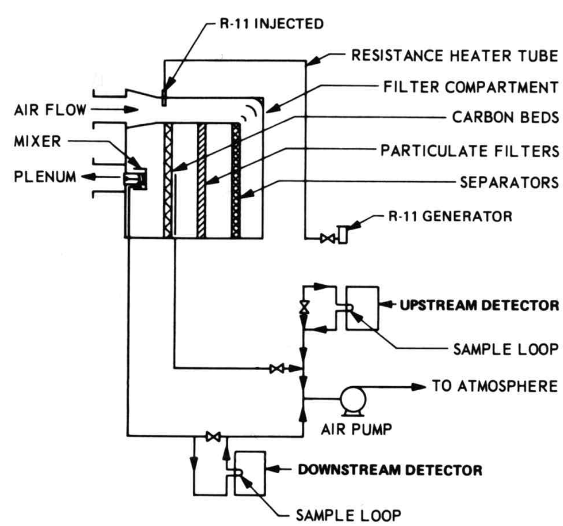



Figure 8.12 – Schematic of charcoal testing setup

developed to give the required test precision. At ORNL, a combination of sampling and injection rates is selected which, with available counting equipment, will produce an upstream sampler radioactivity count between 8 x $10^5$ and 5 x $10^6$ counts/min. These are not rigid limits, but are instead convenient target values with considerable latitude. Satisfactory tests have been made with sampling rates as low as 0.03 percent of the system flow rate, but sampling rates of about 1.0 cfm per 1,000 cfm (0.1 percent) of rated adsorber capacity are recommended.

The amount of iodine required and the size of the injector tube are not critical. The amount of iodide-127 is invariably 100 mg in the ORNL tests, although this amount may be doubled if excessive plateout in the upstream duct or housing occurs. The amount of iodide-131 tracer must be adjusted to give the radioactivity count noted above. The radioactive iodine source is prepared by mixing the required quantities of iodide-127 and iodide-131 as sodium iodine, precipitating the iodine fraction of palladium iodide by treatment with acidified palladium chloride, then decomposing the palladium-iodide under vacuum. The liberated iodide-127 and iodide-131 is collected in a liquid-nitrogen-cooled U-tube and transferred to a glass ampule that is installed in the injector (FIGURE 8.13). Preparation of the iodine and loading of the injector must be carried out in a laboratory equipped for handling radioactive materials. To inject iodine during the test, the injector tube is crushed, breaking the ampule and releasing the iodine vapor. Compressed air is passed through the tube at a carefully controlled rate for about 2 hrs. During the final half-hour, heat is applied to the injection tube to drive out the remaining iodine.

**FIGURE 8.15** shows a typical in-place radioiodine-tracer test setup. After system flow and background radioactivity levels are established, iodine is injected far enough upstream to ensure adequate mixing with the main airstream, and samples are withdrawn simultaneously through the upstream and downstream sampling units. Injection of iodine is continued for approximately 2 hrs, but system airflow and downstream sampling are continued for another 2 hrs to catch any iodine that may desorb from the beds, in addition to that which penetrates immediately. Exhaust air from the sampling units is usually dumped back into the upstream side of the main system. The iodine content of the carbon in the samplers is determined by direct gamma spectroscopy, and the bypass leakage is determined from the following equation.

$$E = ( \frac{1 - Cd}{Cu - B}$$

Where

E = efficient, percent

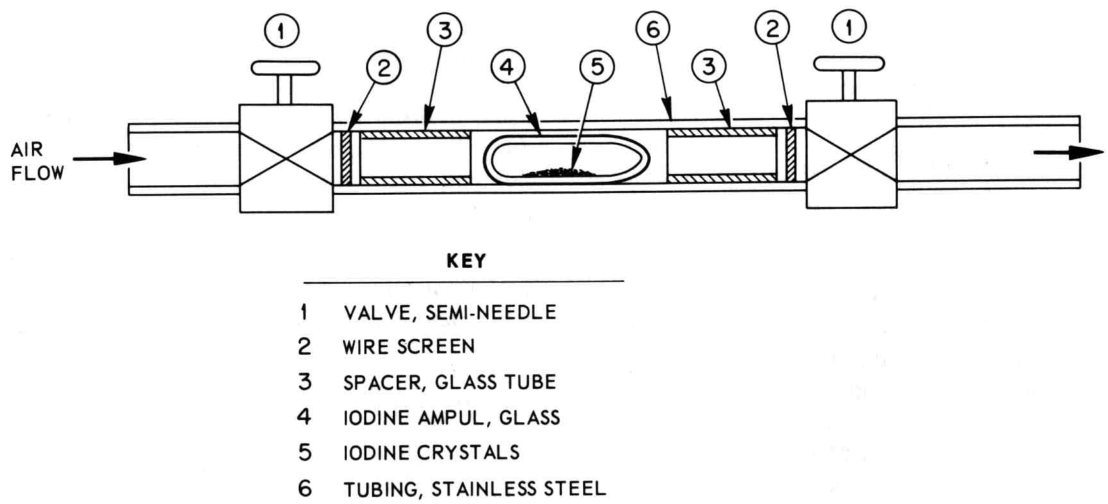



Figure 8.13 – Injector tube for radioactive tracer test

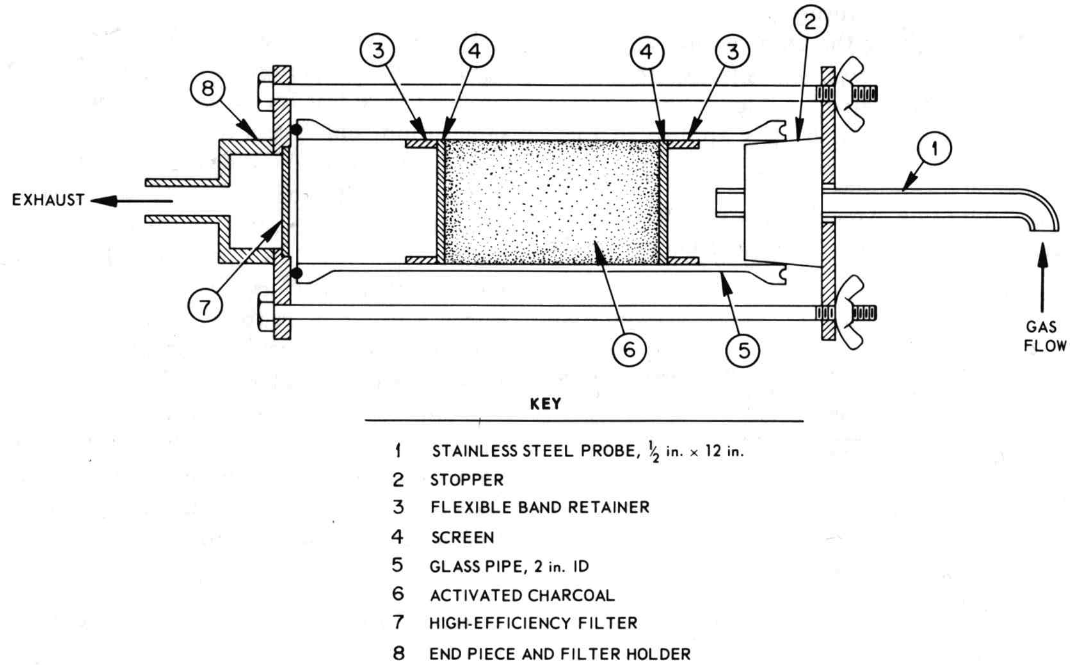



Figure 8.14 – Sampling elements for radioactive tracer test

Cd = iodine content of downstream unit, dis/min

Cu = iodine content of upstream unit, dis/min

B = background due to impurity iodine is charcoal, dis/min

The methyl iodide test for determining the efficiency of adsorbers for organic radioiodine compounds is similar to the test for elemental iodine and uses the same equipment, except for the injector. The injector used for the methyl iodide test is a U-tube and a vapor expansion chamber. Sampling and analytical procedures are the same as those for the elemental iodine test. The test vapor is methyl iodide-127 containing methyl iodide-131 tracer. Because the methyl iodine test determines a different property of the adsorbent and depends on a different sorption mechanism, it cannot be used in place of the elemental iodine test. Therefore, both tests are required for a complete evaluation of impregnated charcoal adsorbers. Both of these tests suffer from the limitations of using radioactive tracers in the field and from the number of variables that must be controlled to achieve reliable results.

### 8.6.3 Test Sequence and Frequency

The recommended test sequences and frequencies in both ASME N510[10] and USNRC Regulatory Guides 1.52[13] and 1.140[14] are inadequate to ensure that an air cleaning system is maintained in an acceptable operational condition. In addition, ASME AG-1, Section TA,[3] and ASME N511[12] provide updated guidance on testing sequence and frequency.

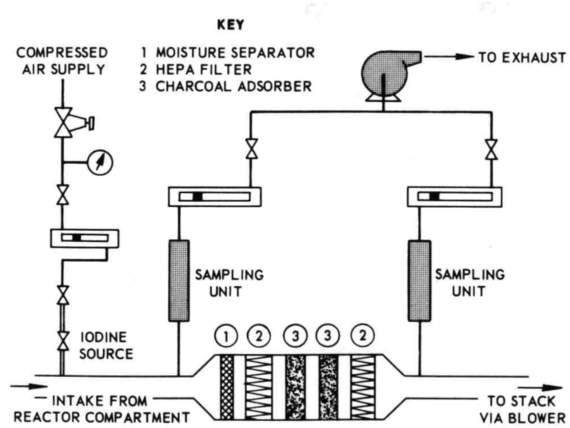



Figure 8.15 – Test setup for radioiodine tracer tests

Surveillance Tests

Surveillance tests are outlined in Table 1 of ASME N510,[10] and are repeated in **TABLE 8.2** below.

Table 8.2 – Surveillance Tests

| **Test** | **Recommended Frequency** Note 1 |
|---|---|
| Visual Inspection | Before each test series Note 2 |
| Duct Leak Test | Acceptance Note 3 |
| Structural Capability Test | Acceptance Note 3 |
| Housing Leak Test | Acceptance and at least once each ten years Note 3 |
| Mounting Frame Pressure | Optional Leak Test Note 4 |
| Airflow Capacity/Distribution | Acceptance Note 3 Surveillance Note 5 |
| Air-aerosol Mixing Uniformity | Acceptance Note 3 Test |
| In-place Leak Test HEPA | Acceptance after each HEPA filter replacement and at least once each operating cycle (every 12 months for DOE sites as a basis or more/less frequency, as determined by a technical evaluation) Notes 3, 6 |
| In-place Leak Test Adsorbers | Acceptance after each adsorber replacement and at least once each operating cycle Notes 3, 6 |
| Duct Damper Bypass Test | Acceptance and at least once each operating cycle Notes 3, 6 |
| System Bypass Test | Acceptance and at least once each operating cycle (See HEPA above) Notes 3, 6 |
| Air Heater Performance Test | Acceptance and at least once each operating cycle Note 3 |
| Laboratory Test of Adsorbent | Acceptance before each adsorber replacement, and at least once each operating cycle Notes 3, 7, 8 |

Notes:

1. Field test of motors, valve and damper actuators, and fire protective systems are not covered in ASME N510 [10].
2. The frequency of verifying loop seals and traps must be evaluated by the owner to assure integrity at all times.
3. Acceptance tests must be made after completion of initial construction and after any major system modification or repair.
4. The mounting frame leak test is a recommended, but optional, test that identifies the mounting frame leakage that would be included as a part of total bank leakage during HEPA filter bank and adsorber bank in-place leak tests. In many cases, a thorough visual inspection of the mounting frame ensures the mounting frame leakage component of total bank leakage will be minimal (significant leak paths can be visually located). It is left up to the owner to determine whether a mounting frame leak test is warranted based on the visual examination.
5. Airflow capacity checks for surveillance purposes must be performed prior to any in-place leak test.
6. Periodic in-place leak tests of systems located within reactor containments and used only for 100 percent recirculation are not necessary.
7. Adsorbents must be tested before installation or replacement to establish efficiency. Samples for laboratory testing should be taken before routine in-place testing of the installed system to verify the condition of the adsorbent.
8. Adsorbent must be sampled and laboratory tests must be conducted to confirm performance at intervals not exceeding 720 hrs of system operation for any system immediately following inadvertent exposure to solvent, paints, or other organic fumes or vapors that could degrade the performance of the adsorbent. The 720-hr requirement may be modified based on laboratory test history.

Additionally, due to the potential for unauthorized flow adjustment and duct damage, all air cleaning system airflows should be rebalanced at least every 5 years.

## 8.7 IN-PLACE TESTING FOR MULTISTAGE SYSTEMS

Systems that contain two or more HEPA filter stages and/or two or more adsorber stages in series in the same housing give special problems because of the difficulty of obtaining a representative single-point sample downstream of the first bank and the difficulty of introducing the second-stage test aerosol at a point where good mixing can be achieved. Series banks are usually too close, so neither of these objectives can be achieved in the normal manner. Because of the high collection efficiency of the first-stage elements, sufficient test aerosol cannot be introduced upstream of the first stage to permit effective testing of the second stage. It has been shown that accepted test aerosols have no adverse effect on activated carbon or other adsorbents when used for testing nuclear air cleaning systems,[21] and the refrigerant gases used to date have no adverse effect on HEPA filters.

### 8.7.1 FIRST-STAGE DOWNSTREAM SAMPLE

The first-stage downstream sample can be obtained either by using a multiple sampling technique or by providing a temporary jumper duct to bypass airflow around the second stage to either the system fan, as shown in **FIGURE 8.16**, or to a temporary auxiliary fan. In the arrangement shown in FIGURE 8.16, the downstream housing damper is closed so that no air is brought through the components downstream of the bypass connection. The downstream sample can be taken either upstream of the fan, in the temporary bypass duct (if that duct is long enough to ensure good mixing), or downstream of the fan. [Note that the bypass duct ports must be capped and sealed when not in use.]

For testing multistage HEPA filter banks, scanning the downstream face of the stage to be tested is an approved technique, in accordance with the procedure outlined in Section 4 of Institute of Environmental Sciences (IES) CS-2.[26] The recommended scanning pattern for each filter in the bank is shown in **FIGURE 8.17**. Prior to starting scanning, the upstream side of the stage is challenged with test aerosol and the photometer is adjusted to read 100 percent. A high concentration will always exist directly downstream of a leak. During the downstream scan, the relative magnitude of each leak is determined by turning the scale shift knob of the instrument until a reading about halfway between half and full scale is obtained. The reading is recorded, and the leak flow for that point is calculated from the following equation.

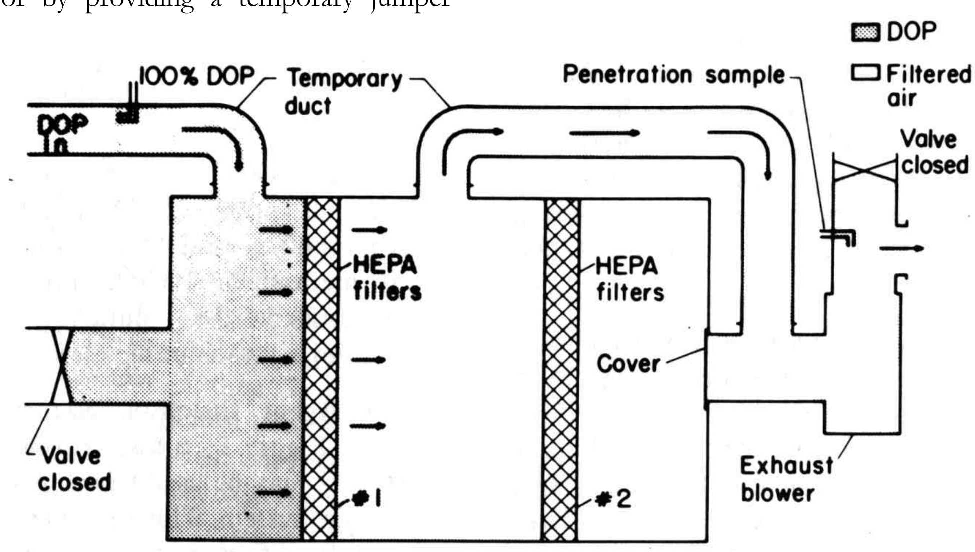



Figure 8.16 – Airflow bypass to system fans